Integrative Medicine Research

journal homepage: www.imr-journal.com

Review Article

Development of pulse diagnostic devices in Korea

Hyunho Kim[a], *Jong Yeol Kim*[b], *Young-Jae Park*[a], *Young-Bae Park*[a,*]

[a] *Department of Biofunctional Medicine and Diagnostics, College of Korean Medicine, Kyung Hee University, Seoul, Korea*
[b] *Medicine Research Division, Korea Institute of Oriental Medicine, Daejeon, Korea*

ARTICLE INFO

Article history:
Received 28 January 2013
Received in revised form
30 January 2013
Accepted 31 January 2013
Available online 13 February 2013

Keywords:
Pressure pulse waveform
Pulse diagnosis
Pulse diagnostic device

ABSTRACT

In Korean medicine, pulse diagnosis is one of the important methods for determining the health status of a patient. For over 40 years, electromechanical pulse diagnostic devices have been developed to objectify and quantify pulse diagnoses. In this paper, we review previous research and development for pulse diagnostic devices according to various fields of study: demand analysis and current phase, literature studies, sensors, actuators, systems, physical quantity studies, clinical studies, and the U-health system. We point out some confusing issues that have been naively accepted without strict verification: original pressure pulse waveform and derivative pressure pulse waveform, pressure signals and other signal types, and minutely controlled pressure exertion issues. We then consider some technical and clinical issues to achieve the development of a pulse diagnostic device that is appropriate both technically and in terms of Korean medicine. We hope to show the history of pulse diagnostic device research in Korea and propose a proper method to research and develop these devices.

1. Introduction

Pulse diagnosis is a palpation method that is one of the four diagnostic examinations of Korean medicine. It is a diagnostic method in which a doctor uses finger sensations to observe the pressure pulse waveform (PPW). Korean medical doctors consider this PPW information to understand a patient's health condition or validate medical treatment. In the early days, doctors sensed PPWs at various sites over the whole body, but this has changed to the wrist pulse-taking method. Pulse diagnosis has very high diagnostic importance and significance in Korean medicine, but it depends on a doctor's subjective sensations and oral tradition. To overcome these issues, many studies have been conducted on the objectification and quantification of pulse diagnosis, and electromechanical pulse diagnostic devices have been invented.

The first wrist pulse diagnostic device was developed in 1968, by Dr. Bong-Kyo Lee, with the opening of Kyung Hee University Oriental Medicine Hospital. Many studies were then conducted on the PPW-generating mechanism, the physical meaning of the PPW, electromechanical sensors, pulse diagnostic device systems, database management systems, and clinical trials, However, the low reliability and controversial validity resulting from the limitations of sensors and actuators, and the lack of understanding among Korean medical doctors, made clinical utilization of the devices very low. Nowadays, engineering techniques and applications have

* Corresponding author at: Department of Biofunctional Medicine & Diagnostics, Kyung Hee University Oriental Medicine Hospital, #1 Hoegi-dong, Dongdaemun-gu, 130-702, Seoul, Korea
E-mail address: bmppark@khu.ac.kr (Y.-B. Park).
http://dx.doi.org/10.1016/j.imr.2013.01.003

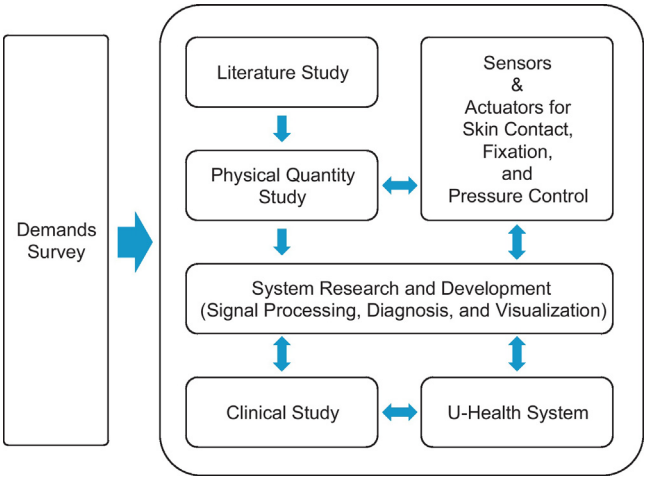

Fig. 1 – Brief diagram of study flow in research and development for pulse diagnostic devices.

seen very rapid advances, so sensors and actuators have become highly developed, and Korean medical doctors' understanding of the objectification and quantification of clinical data has greatly improved. Under these conditions, the need for reliable pulse diagnostic devices has become prominent.

However, there have been few reviews on the objectification of the pulse diagnosis in Korea, even though many studies have been conducted on this issue. Thus, in this paper, we review previous studies on pulse diagnostic devices to discuss present trends and some issues that should be resolved. Section 2 reviews previous studies in many related fields. We then discuss some technical and clinical issues in Section 3. Conclusions are drawn in Section 4.

Studies on pulse diagnosis include photoplethysmography (PPG) and pulse wave velocity (PWV) research in a broad sense. Strictly speaking, however, they are not "wrist PPW studies". Thus, PPG and PWV research and developments related to PPG and PWV have been excluded from this paper.

2. Overview of research and development of pulse diagnostic devices in Korea

Fig. 1 shows a brief diagram that expresses the study flow of research and development for pulse diagnostic devices. In Section 2, we review each stage of the flowchart.

2.1. *Demand analysis and current phase*

According to a research survey in 2009, 159 Korean medical doctors showed a neutral attitude toward the importance of pulse diagnostic devices,[1] whereas 121 Chinese medical doctors showed a positive response.[2] In a 2010 survey, 105 Korean medical doctors still showed a neutral attitude.[3] The surveys reported common problems with the reliability and validity of the devices. In another study in 2009, only 13% of the respondents said that they used pulse diagnostic devices in their clinics.[4]

Although pulse diagnosis using pulse diagnostic devices is supported by Korea's national insurance scheme, the number of pulse diagnostic devices in use decreased from 3055 in 2002 to 2010 in 2010.[5] Despite inclusion of the approach in the national insurance scheme and the increase in the number of Korean medical clinics, this decrease in usage means that current commercially available devices cannot provide clinical support and economic benefit.

2.2. *Literature studies*

Literature reviews on pulse diagnosis have mainly involved translation and interpretation. In particular, medical historical reviews have discussed 12 meridian pulse-taking methods, three position and nine indicator pulse-taking methods, and carotid and wrist pulse-taking methods.[6–10] Studies have been conducted on the definitions and positioning of *chon*, *gwan*, and *cheok* [*cun*, *guan*, and *chi* in the World Health Organization (WHO) international standard terminologies on traditional medicine in the western Pacific region], studies on matching viscera and bowels to *chon*, *gwan*, and *cheok*;[11–16] and Korean medical physiologic and pathologic studies on specific PPWs.[17–20] The reinterpretation and English translation of pulse diagnosis sections of the *Nan Jing* using WHO international standard terminologies for traditional medicine in the western Pacific region have been reported.[21–23] However, these studies cannot be applied in clinics without strict verification because they mainly focused on the translation and interpretation of the classics, as noted above, and they cite abstract expressions of the traditional medical classics repeatedly and in circular fashion.

The other stream involves studies of the description and classification of the PPW;[24–29] this is reviewed in detail in Section 2.4 with the physical quantity studies. This area is very important to the research and development of pulse diagnostic devices because these studies can provide many important clues to the physical attributes of the PPW detected by the devices. However, the classics describe the PPW mainly in metaphorical, symbolic, and poetic ways.[30] Thus, to modernize pulse diagnosis, the PPW should be studied according to scientific and analytic methodologies.

2.3. *Sensors, actuators, and systems*

The structure of wrist pulse diagnostic devices is divided into the sensor, the skin contact and pressure-controlling part, the signal-processing part, and the visualization part. In this paper, we focus on the first two because the latter two use a wristband-type embedded system or personal computer system.

2.3.1. *Sensors*

Sensors are very important because they are the core modules which pick up and quantify the PPW signal. In particular, the physical fundamentals and form characteristics directly influence the methodology used to analyze the PPW and play a definite role in studies on reliability and validity.

Pulse diagnostic devices in Korea have used piezoelectric devices,[31–33] piezoresistive strain gauges,[34–37] air-vibration-detecting condenser microphones,[38,39] optical fiber

Table 1 – Direct measured physical parameters according to sensor type.

Sensor type	Measured physical parameter
Piezoelectric device	Pressure (derivative function)
Piezoresistive strain gauge	Pressure
Condenser microphone	Air vibration
Optical fiber transducer	Displacement
Optical coherence tomography device	Displacement
Fiber Bragg grating	Displacement
Magnetic junction element	Displacement
Magnetic Hall device	Displacement
Moving pulse image	Displacement

transducers that use the reflective optical power change according to infinitesimal displacement,[40] optical fiber coupling controlled by infinitesimal displacement,[41,42] optical coherence tomography devices using in-line Michelson interferometers,[43–46] fiber Bragg gratings,[47] magnetic junction elements,[48] magnetic Hall devices,[49–55] moving pulse images,[56,57] and so on.

The physical fundamentals of the sensors determine the dimensions of the measured signal. Some sensors detect the original PPW, whereas others detect the derivative of the original PPW. This derivative PPW gives the change rates of the pressure pulse directly but does not reveal anything about the original PPW.[30,58] In other cases, because the measured data reflect an indirect or partial physical quantity of the PPW, the signal should be transformed to the original PPW through strict physical calculations. Some examples include the condenser microphone, optical fiber transducer, and magnetic junction element. Recently, piezoresistive strain gauges and magnetic Hall devices have been used in the pulse diagnostic devices, and a system with a piezoelectric film sensor and conductive textile has been reported.[33] Table 1 lists directly measured physical parameters according to the sensor types.

2.3.2. *Actuators for skin contact, fixation, and pressure control*

Actuators for skin contact, fixation, and pressure control are also very important because only correct and firm fixation can guarantee the reliability of the devices. In addition, pressure must be applied perpendicular to the artery in the tonometric pressure measurement system. If not, the perturbation can drive fluctuation of the signal, and the measured data will not reflect the correct PPW.

The pressure-exerting system must be quantified and controlled correctly. In Korean medicine, pulse diagnosis does not mean pulse palpation at the skin surface without pressure, but the sensation of the PPW response to various pressures exerted by the doctor's fingertips. Early pulse diagnostic device models did not include the concept of minutely controlled applications of pressure,[59] but as the importance of the exerted pressure became highly emphasized, pressure control systems with air-pressure control[60,61] or a robotic arm[62] were developed. These systems have been used in basic measurement studies according to the exerted pressure,[63,64] hemodynamic studies,[65,66] pressure control method studies,[67–69] and research into pressure training systems.[70] Patents relating to the skin contact, fixation, and pressure control system are continuously being filed.[4]

2.3.3. *Pulse diagnosis systems*

The first pulse diagnosis system in Korea was the Bong-Kyo type, which was invented in 1968 by Dr. Bong-Kyo Lee using one piezoelectric sensor; he uncovered major features of eight basic pulses by clinical research conducted using this system. The system measured the derivative PPW. Fixation was performed with wristbands, and it was impossible to quantify the exerted pressure. This model was not meant for commercial use, but it was the first approach that reflected the basic theories of Korean and Western medicine and reported clinical meanings.[38,58]

In 1972, Hee-Soo Paek announced that the experimental model of the Hee-Soo type pulse diagnostic device would go on the market. The Hee-Soo type device at first used piezoelectric sensors, which were then changed to condenser microphone sensors. It could exert pressure with a cuff, but quantification and control of the exerted pressure were still impossible. Measured data from the Hee-Soo-type model were repeatedly differentiated and integrated by the numerical method through signal-processing, so there was a great deal of data loss in the results, which was a critical defect. Thus, controversy over the validity—that is, whether or not the signal from the condenser microphone was a reflection of the radial artery PPW—was the main problem of the Hee-Soo-type model.[30,38,39,58]

In 1986, Sord Medicom Company developed the Sord-type pulse diagnostic device. Three-channel piezoelectric sensors were used in the Sord-type device, which was based on the Bong-Kyo-type model. First, a fixed sensing part was used; afterward, a glove with sensors in its fingertips was developed. The device was still limited by the derivative PPW and an inability to quantify the exerted pressure.[30,38,58]In the late 1990s, Dr. Young-Bae Park of Kyung Hee University Oriental Medical Hospital used a piezoresistive strain gauge to overcome the limitation of the derivative PPW;[34,36,71–73] afterward, this model was developed into a system detecting the pulse–respiration ratio, in which the pulse and respiration signal were considered together to understand a patient's health state.[24,74–76]

With the start of the new millennium, a brand-new model using array strain gauge sensors was invented by the Daeyomedi Company and the Korea Institute of Oriental Medicine[37,61] to solve the problem of quantifying the exerted pressure, to record the three-dimensional waveform with pulse width information, and to detect the original PPW. Table 2 briefly presents the characteristics of the Bong-Kyo type and other commercial models.

2.4. *Studies on physical quantification*

Studies on the physical quantities of the PPW can be divided into two types: studies on the pulse diagnosis act and PPW written in the traditional medical classics, and studies from the hemodynamic point of view. The former seek to answer the question, "How can we reconstruct the Korean medical pulse diagnosis in a scientific and engineering-based way, and how can we interpret the definition of a PPW written in

Table 2 – Characteristics of pulse diagnostic device systems.

Device type	Bong-Kyo type	Hee-Soo type	Sord type	Daeyomedi type
Year	1968	1972	1986	2001
Sensor type	Piezoelectric sensor	Condenser microphone	Piezoelectric sensor	Piezoresistive strain gauge
Fixation	Band	Cuff	Clamp/finger	Robot arm
Pressure control	Impossible	Impossible	Impossible	Possible
Output waveform	Derivative PPW	Air vibration	Derivative PPW	Original PPW

PPW, pressure pulse waveform.

the classics?" This question is closely related to the belief in Korean medicine that pulse diagnosis is an important holistic reflection of health and disease. Meanwhile, the latter answers the question, "What are the feature parameters of the PPW, and what is the cardiovascular meaning of these hemodynamic parameters?" The Korean medical meaning of pulse diagnosis is excluded from this type of study. PPW feature selection, aging or the physical quantity of blood pressure itself, hemodynamic study, and structural or functional disorders following the structural disorders of the heart are the main topics of study here.

Physical quantity studies for PPW structure analysis start with the literature reviews discussed in Section 2.2. Researchers have determined physical quantities from the classics through logic and specific established parameters,[13,25,26,28,29,44,77–83] and have applied these parameters to signal-processing procedures. Studies of carotid–wrist pulse-taking,[71,84] studies of rapid, slow, and moderate pulses based on the pulse–respiration ratio,[24,74,85,86] studies of floating and sunken pulses,[87–93] the string-like pulse,[94] and vacuous and replete pulses,[95,96] correlation studies of expert diagnosis;[97] and studies on anatomical and hemodynamic PPWs[98] have been conducted.

The signal-processing technique or data-mining methodology has been applied to PPW feature selection studies.[99–109] PPW analysis with Fourier transform[110,111] and wavelet transform,[112,113] and respiration rate extraction using fast Fourier transform[114] have been conducted. Furthermore, statistical analysis of PPW parameters,[115] neuro-fuzzy analysis,[116] clinical studies on hypertension,[117–119] studies on aging[120] and arteriosclerosis,[121] and studies using modeling and simulation[122,123] have been reported.

In addition, attempts have been made to match the extracted parameters with five-phase theory,[101,102,106,109,124] but they have little validity from the Korean medical point of view.

2.5. *Clinical studies*

There is little evidence on the relationship between the PPW and disease except for written expressions in the traditional medical classics. Furthermore, because discussions have cited abstract expressions of the traditional medical classics repeatedly and in a circular fashion, pulse diagnosis should be clinically verified. Clinical trials have been continuously reported to confirm the clinical meaning of pulse diagnosis and analyze new diagnostic parameters. Clinical studies can be divided into four fields: the examination of healthy people, studies into examination of the constitution, the examination of specific diseases, and application as the evaluation index after Korean medical treatments. PPW variations according to sex,[125] age,[126–132] body mass index,[133–135] sensing sites,[136] and meals[137–140] have been reported. Studies related to the Sasang constitution theory include characteristics studies[141–146] and constitution diagnostics studies.[147–149]

Various clinical trials on specific diseases have been performed, but they were mainly PPG[150–159] or PWV[160–164] studies. Apart from those studies, clinical trials have been performed in the areas of stroke,[165] hypertension,[117,144,166,167] arrhythmia,[138] respiratory symptoms,[168,169] sterility,[170,171] diabetes mellitus,[172] digestive symptoms,[173,174] atopic dermatitis,[175] metabolic syndrome,[131] and thyroid disorders.[85] PPW parameters have been used to evaluate the effect of Korean treatments, for example normal acupuncture,[176–178] bee venom pharmacoacupuncture,[179] and wild ginseng pharmacoacupuncture.[180] In addition, agreement between interpretations,[181] correlation between red blood cell volume and PPW,[182] blood characteristics,[183] and PPW measuring sites[184,185] have all been studied.

Almost all clinical studies have focused on the physical parameters of PPW and not on the pulse phase (e.g., floating pulse or sunken pulse) itself. In addition, statistical looseness and incorrect methodologies were the weak points of the previous clinical studies. Study groups were limited to the Korea Institute of Oriental Medicine, Kyung Hee University, and Dong-Eui University, showing that wide and varied clinical studies have not been conducted.

2.6. *U-health systems*

U-health is the convergence of ubiquitous computing techniques and medical services. It is defined as a remote service that can collect, process, transmit, and manage various pieces of information from customers without spatiotemporal limitations. Nowadays, many people want not hospital services requiring daily visits, but real-time care and advice services that can check various symptoms and measure biosignals automatically; in an aging society, people focus more on health management and disease prevention than on curing disease. Moreover, with the development of network, computing, and microelectromechanical system technologies, the demands for and expectations from U-health have increased rapidly.

In the field of pulse diagnosis, system research has been combined with the U-health service.[108,186,187] In the U-health system, accessibility, convenience, and fast measurement are important issues. Thus, many PPG studies have been conducted using the wristband form[188] or fingertip probe form.[189–191] In this case, however, the PPG signal, the volume pulse waveform at the fingertip, is different from that from wrist PPW diagnosis, so additional analysis should be

performed. Database management systems to manage the measured information[192–194] and the ontology of the measured PPW[195] have also been studied.

3. Technical challenges and strategies to overcome them

In this section, we discuss the technical challenges for improving the reliability, validity, and utilization of pulse diagnostic devices based on the previous studies reviewed above.

3.1. *Sensors and actuators*

As noted previously, skin contact, fixation, and pressure control are problems related to reliability and validity. Many methods have been developed, but no system can measure the PPW at the three palpation sites—*chon*, *gwan*, and *cheok*—simultaneously with controlling the pressure exerted. To be able to realize traditional Korean medical pulse diagnosis, these technical issues need to be solved. Solutions can involve the research and development of a robotic arm or air pressure control system combined with multichannel piezoelectric films, conductive textiles,[33,196] or array sensors.[37,61,197]

3.2. *Physical quantity studies*

Physical quantity study is closely related to the content validity of pulse diagnostic devices. Misunderstandings of a PPG as a PPW, or a condenser microphone output as a pressure signal, have been naively accepted without definite verification. Thus, correct physical parameter measurements with the appropriate sensor technology should be developed, closely observing the approach of traditional Korean medical pulse diagnosis.

Some sensors detect the derivative PPW rather than the original PPW. Thus, because the PPW means the original PPW, research on derivative PPWs need additional discussion.

3.3. *U-Health systems*

U-health, which is based on wireless sensor networks, big data analysis, and high-speed computing technology, is a major issue for modern medical service and a blue ocean in market terms. Carrier vendors and the manufacturing industry intend to increase their U-health market share with their services, and many U-health service providers recognize healthy and subhealthy people as their sales target. Thus, for U-health pulse diagnostic devices, we must determine parameters that correctly indicate health status, examine the technical merits of measuring various kinds of data in short amounts of time, and facilitate high levels of accessibility with a portable or wearable form user interface.

Pulse diagnosis is a holistic diagnostic method in Korean medicine. If it is integrated with other biosignal information, we can better understand the patient's health status and expand the applicability of Korean medical treatment with regard to U-health.

3.4. *Clinical study issues*

About 40 years have passed since the first pulse diagnostic device was invented, but the problem of insufficient reliability and validity remains unsolved. Additionally, the history of clinical study in Korean medicine is not very long. Therefore, there are limitations to the high evidence level seen in clinical studies, and few clinical studies have been well designed either statistically and methodologically. Statistical and clinical applications should be understood deeply and analyzed carefully. Correlation between PPW parameters and clinical symptoms or diseases is usually misunderstood as causality.

A diagnostic device can be verified only after well-designed clinical studies have been conducted. We expect many hospitals or clinical research centers to perform proper clinical trials with the development of these devices themselves.

4. Conclusion

We have reviewed previous studies on pulse diagnostic device research and development according to various fields of study, and have discussed some issues related to the further development of pulse diagnostic devices that need resolving. Pulse diagnosis is a distinct and holistic method for gathering health information from patients in Korean medicine. It plays a critical role in differential diagnosis and in evaluation of the treatment effect. As the objectification and quantification of data- and evidence-based medicine are areas that are currently strongly emphasized, an appropriate pulse diagnostic device that reflects the approach of Korean medical will be helpful to accomplish the globalization and rationalization of Korean medicine. We hope that this review will stimulate more technical research and development and be a useful guide for realizing this goal.

Conflicts of interest

All contributing authors declare no conflict of interest.

REFERENCES

1. Kim GC, Kim JH, Shin WJ, Lee HW, Kang HJ. A study on the research demands for the pulse analyzer. *Korean J Orient Prevent Med Soc* 2009;13(Suppl 1):29–40 [In Korean, English abstract].
2. Kim GC, Kim JH, Shin WJ, Lee HW, Park JY, Hong SM, et al. The statistical analysis for cognizance on the Chinese Oriental medical doctor of the pulse meter-analyzer. *J Korea Inst Orient Med Diagn* 2009;13(Suppl 2):88–116 [In Korean, English abstract].
3. Kim GC, Park SW, Song KH, Park JY, Hong SM, Lee HW. Clinical demands for evidence-medical interventions and diagnostic technology in Oriental medicine. *Korean J Orient Prevent Med Soc* 2010;14(Suppl 2):121–33 [In Korean, English abstract].
4. Lee YJ, Lee J, Kim JY. Suggestion on an innovative pulse diagnosis system based on technical trend analysis. *Korean J Orient Physiol Pathol* 2009;23(Suppl 1):174–9 [In Korean, English abstract].

5. Bak YH, Kwon JW, Huang DS, Shin HK. Study of medical devices in traditional Korean clinics. *J Korean Orient Med* 2011;32(Suppl 2):79–91 [In Korean, English abstract].
6. Sin KW, Jang JH, Yoon JH. A study on diagnosis method by chonguinyoung pulse based on *Youngchu Kyoungmaek*. *J Korean Acupunct Moxibustion Soc* 2002;19(Suppl 1):203–9 [In Korean, English abstract].
7. Lim SC, Son SC, Lee KM, Hwang MS, Kim KS, Yoon JH. The study of pulse diagnosis about twelve meridians. *J Korean Acupunct Moxibustion Soc* 2002;19(Suppl 5):1–9 [In Korean, English abstract].
8. Hwang JI, Lee JB, Hwang MS, Yoon JH. Research of Qijingbamai pulse diagnosis method, Qikoujiudaomai. *J Korean Acupunct Moxibustion Soc* 2005;22(Suppl 4):165–78 [In Korean, English abstract].
9. Kim GW. Early change of carotid-wrist pulse-taking method. *J Korean Med Classics* 2006;19(Suppl 1):16–25 [In Korean].
10. Park HK, Kim KW. A study on HuangDiNeiJing SanBuJiuHouLun. *J Korean Med Classics* 2006;19(Suppl 1):26–40 [In Korean, English abstract].
11. Yang GI, Park K. A study on the pulse's division named chon kwan chuk by the viscera and the entrails and on the pulse of disease according to Eum-Yang. *J Korea Inst Orient Med Diagn* 2001;5(Suppl 2):233–61 [In Korean, English abstract].
12. Lee SK, Park WH. A study on the cun, guan, chi from the elementary course for medicine (Yi Xue Ru Men). *J Korea Inst Orient Med Diagn* 2005;9(Suppl 2):10–24 [In Korean, English abstract].
13. Kim H, Lee J, Kim GW, Kim JY. Proposal for pulse diagnosis positions (chon-kwan-chuk) for pulse analyzer based on literature review and anthropometry. *J Korean Orient Med* 2007;28(Suppl 3):13–22 [In Korean, English abstract].
14. Jung CW, Yoon CY. A study on matching chon kwan chuk to the viscera and the entrail. *J Korean Med Classics* 2008;21(Suppl 4):29–40 [In Korean, English abstract].
15. Yang KY. A study on the assignment of jangbu to chon gwan cheok in Maekyojeongmiron. *J Korean Med Classics* 2009;22(Suppl 1):27–34 [In Korean, English abstract].
16. Kim JG. The study on the interrelationship of fixing the ki-gu pulse and the yin-yeong pulse in front of kwan the distance of 1 pun and the development of the kwan-pulse. *J Korea Inst Orient Med Diagn* 2009;13(Suppl 2):14–23 [In Korean, English abstract].
17. Sung BM, Park K. A Study on the pulse conditions and symptoms of diseases related with pathogenic factor of deficiency type, excess type, zei pathogenic factor and indistinct pathogenic factor of the five viscera in the third volume in the Maek Kyoung II. *J Korea Inst Orient Med Diagn* 2005;9(Suppl 1):23–46 [In Korean, English abstract].
18. Sung BM, Park K. A study on the pulse conditions and symptoms of diseases related with pathogenic factor of deficiency type, excess type, zei pathogenic factor and indistinct pathogenic factor of the five viscera in the third volume in the Maek Kyoung III. *J Korea Inst Orient Med Diagn* 2005;9(Suppl 2):57–71 [In Korean, English abstract].
19. Baik YS. A study on pulse condition of Sameumsamyang in "Hwangjenaegyeong". *J Korean Med Classics* 2008;21(Suppl 3):119–25 [In Korean, English abstract].
20. Jang WC. Study on the origin and theoretical foundation of I Dong-won's pulse diagnosis distinguishing internal and external injuries. *J Korean Med Classics* 2007;20(Suppl 2):137–45 [In Korean, English abstract].
21. Kim JK, Kang HW, Baek JU. An English translation study on the ninth through fifteenth issue about pulse diagnosis of "Classic of Difficult Issues". *J Korean Med Classics* 2010;23(Suppl 5):67–82 [In Korean, English abstract].
22. Kim JY, Baek JU. An English translation study on the first eight issues about pulse diagnosis of "Classic of Difficult Issues". *J Korean Med Classics* 2009;22(Suppl 3):187–202 [In Korean, English abstract].
23. Kang HW, Kim JK, Baek JU. An English translation study on the sixteenth to twenty-second issue concerning pulse diagnosis of "Classic of Difficult Issues". *J Korean Med Classics* 2011;24(Suppl 1):57–71 [In Korean, English abstract].
24. Park YB, Kang SK, Kim CH, Kho HK, Kim YS, Lee YH, et al. Detection and interpretation of wan-maeck by the pulse diagnostic apparatus on the pulse/respiration rate. *J Korean Orient Med* 1997;18(Suppl 1):143–56 [In Korean, English abstract].
25. Lee J, Choi H, Kim C. The methodic study on a standard of classification of pulse condition – a focus of the pulse studies of Bin-Ho-. *Korean J Orient Med* 2004;10(Suppl 1):49–61 [In Korean, English abstract].
26. Park JW, Kim BS, Kang JS. Study on classification of pulse condition of the chronological medical practitioners. *Korean J Orient Physiol Pathol* 2008;22(Suppl 6):1347–53 [In Korean, English abstract].
27. Han B. A study on images of the pulse diagnosis. *Korean J Orient Med* 2009;15(Suppl 2):101–9 [In Korean, English abstract].
28. Chung C, Yoon C. Study on the definitions of pulses of "Maekgyeol" by comparison of "Maekgyung" and "Maekgyeol" and "Maekgyeolganoh". *J Korean Med Classics* 2010;23(Suppl 5):103–16 [In Korean, English abstract].
29. Hong S, Park H. A study on the deficiency-excess pattern of the rapid pulse. *Korean J Orient Med* 2010;16(Suppl 3):33–44 [In Korean, English abstract].
30. Kim JY. A Study on the problems and the method for improvement of pulse analyzers. *J Korea Inst Orient Med Diagn* 1999;3(Suppl 1):28–36 [In Korean, English abstract].
31. Yoon DW. Developments of pulse diagnostic apparatus with sensor transducer. *J Korea Inform Commun Soc* 1999;24(Suppl a11):1800–5 [In Korean, English abstract].
32. Yoon YZ, Joh JH, Johng HM, Shin HS, Soh KS. Contrivance of a radial pulse measuring system with variable contact pressure. *J Biomed Eng Res* 1999;20(Suppl 5):567–72 [In Korean, English abstract].
33. Kim J, Jee SH, Yoo SK. Fabrication and evaluation of sensor for measuring pulse wave velocity using piezo film and conductive textile. *J Sensor Sci Technol* 2012;21(Suppl 2):135–43 [In Korean, English abstract].
34. Park YB, Lee HJ, Huh W. The development of pulse diagnostic apparatus enable to gain multi-information and its clinical significance. *J Korean Orient Med* 1995;16(Suppl 1):499–504 [In Korean, English abstract].
35. Yi C. Construction of the Mac Wave Detection System using strain gauge. *J Institute Electron Eng Korea* 1999;36(Suppl 4):88–93 [In Korean, English abstract].
36. Lee HJ, Kim JW, Kim HO, Park YB, Hur W. Radial pulse wave detection system for the Korean medicine. In: *Proceedings of the KOSOMBE Autumn Conference (Suppl 11)*. 1991:66–9 [In Korean, English abstract].
37. Kim EG, Heo H, Nam KC, Kang HJ, Hur Y. Development of 3-channel pulse wave measurement system. In: *Proceedings of the IEEK Summer Conference 31(Suppl 1)*. 2008:1049–50 [In Korean, English abstract].
38. Han CH, Moon SK, Koh CN, Cho KH, Kim YS, Bae HS. Comparison of the waveforms of the three kinds of electronic pulse analyzer. *Korean J Orient Int Med* 1997;18(Suppl 2):207–19 [In Korean].
39. Kim E, Kim B, Kang J. Study on reillumination of Hi-soo type electronic manometer. *J Daejeon Orient Med* 2009;18(Suppl 2):37–45 [In Korean, English abstract].

40. Park SH, Jeong DM, Min HK, Hong SH. Noninvasive detection of radial pulse wave by fiber-optic transducer. *J Biomed Eng Res* 1989;10(Suppl 3):229–36 [In Korean, English abstract].
41. Park SH, Hong SH. Detection of radial pulse by combinational fiber-optic transducer. *J Korean Sensors Soc* 1998;7(Suppl 3):197–202 [In Korean, English abstract].
42. Han SH, Kwon OS, Park SH, Hong SH. Development of P-5 transducer or detection of the pulse wave. In: *Proceedings of the KOSOMBE Autumn Conference 19(Suppl 2)*. 1997:395–8 [In Korean, English abstract].
43. Um SH, Park JH, Kim KC, Kim GT, Lee WK, Kang JK, et al. Optical fiber arterial pulse wave sensor. In: *Proceedings of the Optical Society of Korea Conference*. 2009:380–1 [In Korean, English abstract].
44. Na CS, Youn DH, Kim YS, Lee CH, Jung WS, Kim JH, et al. The study of non-contact/non-invasive pulse analyzing system using optical coherence tomography (OCT) for Oriental pulse diagnosis. *J Meridian Acupoint* 2009;26(Suppl 2):1–13 [In Korean, English abstract].
45. Eom S, Park J, Lee J. Optical fiber arterial pulse wave sensor. *Microw Opt Technol Lett* 2010;52(Suppl 6):1318–21.
46. Jung U, Jeon M, Lee C, Cho N, Jeong H, Na C. Pulse analyzing system using optical coherence tomography for Oriental medical application. *Jpn J Appl Phys* 2011;50(Suppl 5). Article no. 057001.
47. Jeon YJ, Lee J, Ryu HH, Lee JH, Lee SW, Kim JY. Development of the pulse analyzing system using FBG. *Korean J Orient Med* 2007;13(Suppl 3):105–10 [In Korean, English abstract].
48. Kim KS, Kim SW, Kim GW, Lee SJ, Lee SK, Lee HS, et al. Simulation analysis of spatially arterial pulse wave using two-dimensional array sensors with magnetoresistive device. *J Korean Magnetics Society* 2005;15(Suppl 6):307–10 [In Korean].
49. Son IH, Lee SS. Measurement and Analysis of pulse wave using clip type pulsimeter equipped with a permanent magnet and a Hall device. *J Korean Magnetics Soc* 2011;21(Suppl 3):104–7 [In Korean].
50. Yu KD, Hwang SK, Lee SS. Comparison of simultaneously measured pulse waveforms from both hands using permanent magnet-Hall pulsimeter sensor. *J Korean Magnetics Society* 2012;22(Suppl 1):27–31 [In Korean].
51. Jang DH, Kim DB, Choi SK, Lee SS. Measurement of a blood velocity by using photoplethysmograph and radial artery pulse wave equipped with magnetic Hall device. *J Korean Magnetics Society* 2012;22(Suppl 4):130–5 [In Korean].
52. Jin S, Kim MN. Implementation of the pulse wave measurement system using bipolar biased head on mode of the Hall sensor. *J Sensor Sci Technol* 2011;20(Suppl 5):322–8 [In Korean, English abstract].
53. Yu KD, Hwang SK, Choi JK, Son IH, Kim KH, Lee SS. Characteristics of dual handed pulse diagnostic system by using Hall device clip-type pulsimeter. In: *Proceedings of the International Symposium on New Trends in Magnetism and Magnetic Materials*. 2011:123–5 [In Korean].
54. Lee SS, An MC, Ahn SH. A new measurement method of a radial pulse wave using multiple hall array devices. *J Magn* 2009;14(Suppl 3):132–6.
55. Lee SS, Choi JG, Son IH, Kim KH, Nam DH, Hong YS, et al. Fabrication and characterization of a wrist wearable cuffless pulsimeter by using the Hall effect device. *J Magn* 2011;16(Suppl 4):449–52.
56. Lee WB, Choi CY, Hong YS, Lee SS, Nam DH. Pulse wave measurement system by analyzing a moving pulse image in the capillary Tube. *J Inst Webcasting Internet Telecommun* 2012;12(Suppl 2):145–51 [In Korean, English abstract].
57. Kim KW. 2-Dimensional measurement of arterial pulse by imaging devices. *J Korea Inst Oriental Med Diagn* 2008;12(Suppl 2):8–17 [In Korean, English abstract].
58. Park YB. Present and prospect of pulse diagnostic apparatus. *J Korea Inst Orient Med Diagn* 1997;1(Suppl 1):86–94 [In Korean, English abstract].
59. Kim GC, Shin SS, Kang HJ, Cha CY. The basic investigation for the objective study on the pulsation. *Korean J Orient Physiol Pathol* 2003;17(Suppl 5):1147–50 [In Korean, English abstract].
60. Lee J, Jeong M, Hwang S, Lee JH, Lee SK. Multi-point radial artery pulse wave transducer using pneumatic system. In: *Proceedings of the Spring Symposium of Korean Society for Precision Engineering*. 2001:243–8 [In Korean, English abstract].
61. Kim EG, Heo H, Nam KC, Huh Y. 15 Channel tonometric radial pulse measurement system using air cuff pressure. In: *Proceedings of the Korean Institute of Electrical Engineers Conference*. 2008:205–6 [In Korean].
62. Kang HJ, Lee YH, Kim KC, Han CH. A comparative study of methods of measurement of peripheral pulse waveform. *J Korean Orient Med* 2009;30(Suppl 3):98–105.
63. Kim GC, Lee JW, Ryu KH, Kim JH, Park JY. A study on the waveform analysis of left kwan pulse diagnosis by the pressure. *J Korea Inst Orient Med Diagn* 2009;13(Suppl 1):19–35 [In Korean, English abstract].
64. Kim GC, Lee JW, Ryu KH, Kang HJ, Yim YK. Study on the difference of pulse waveform parameter with applied variations of pressure. *Korean J Meridian Acupoint* 2010;27(Suppl 4):59–72 [In Korean, English abstract].
65. Lee Y, Lee J, Ryu HH, Kim JY. A study on hemodynamic characteristics at the occlusion on radial artery. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference*. 2008:1989–90 [In Korean].
66. Lee J, Woo YJ, Jeon YJ, Lee YJ, Kim JY. Development of a measuring system for pulse wave corresponding to different radial artery diameters caused by indentation. *Trans KIEE* 2008;57(Suppl 12):2351–7 [In Korean, English abstract].
67. Lee J, Woo Y, Jeon Y, Lee Y, Ryu H, Kim J. Considerations on an Oriental medical doctor like indentation system. *Korean J Orient Med* 2008;14(Suppl 3):113–9 [In Korean, English abstract].
68. Lee J, Lee YJ, Jeon YJ, Ryu HH, Woo YJ, Kim JY. Development of pulse diagnosis hold-down pressure measurement system. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference*. 2008:1997–8 [In Korean, English abstract].
69. Bae JH, Jeon YJ, Kim JY, Kim JU. Novel detection algorithm of the upstroke of pulse waveform for continuously varying contact pressure method. *J Inst Electron Eng Korea SC* 2012;49(Suppl 2):46–54 [In Korean, English abstract].
70. Lee J, Lee YJ, Jeon YJ, Woo JY, Kim JY. Development of indentation training system for pulse diagnosis. *J Inst Electron Eng Korea SC* 2008;45(Suppl 6):117–22 [In Korean, English abstract].
71. Lee HJ, Kim JW, Hur W. A study on radial pulse diagnosis of the Korean medicine. In: *Proceedings of the KOSOMBE Spring Conference*. 1992:71–4 [In Korean, English abstract].
72. Lee HJ, Park YB, Hur W. Implementation of radial pulse diagnosis system using Inyoung-Cheongu comparison method. *J Biomed Eng Res* 1993;14(Suppl 1):73–80 [In Korean, English abstract].
73. Lee HJ, Hur W. Computerized pulse diagnosis system. *J Inst Electron Eng Korea A* 1996;33(Suppl 4):81–90 [In Korean, English abstract].
74. Han SC, Kim HK, Lee YD, Park YB, Hur W. A study on database for pulse rate diagnosis. In: *Proceedings of the IEEK*

Summer Conference 21(Suppl 1). 1998:569–72 [In Korean, English abstract].
75. Kim HK, Kim HJ, Kim HT, Choi TJ, Byeon MK, Min HK. Implementation of Mac-yule detection system. In: *Proceedings of the IEEK Summer Conference 29(Suppl 1)*. 2006:887–8 [In Korean, English abstract].
76. Byeon MK, Kim HJ, Jang JK, Han SW, Huh W. Development of 3 channel biomedical signal measurement system for Mac-yule. *J IKEEE* 2007;11(Suppl 1):24–9 [In Korean, English abstract].
77. Ryu HH, Lee SW, Lee J, Lee YJ, Kim JY. Analysis of physical quantification of pulse types by pulse diagnosis literatures. *Korean J Orient Physiol Pathol* 2007;21(Suppl 6):1381–7 [In Korean, English abstract].
78. Kim BC, Chae H. Oriental pulse diagnostic apparatus with an emphasis on sense on fingers. *J Inst Signal Processing Syst* 2008;9(Suppl 2):112–20 [In Korean, English abstract].
79. Kim SH, Hong SH, Jung HJ, Park WH. A study on pulse condition appeared at classic with pulse condition by electro pulse machine. *I J Korea Inst Orient Med Diagn* 2009;13(Suppl 1):36–44 [In Korean, English abstract].
80. Jeon YJ, Kim JU, Lee YJ, Ryu HH, Lee HJ, Woo YJ, et al. Characteristic behaviors of the AIx depending on the palpation positions. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference*. 2009:1966–7 [In Korean, English abstract].
81. Kim SH, Lim DG. Pulse diagnosis algorithm and digital filter design for development of digital biomedical system. *J Korea Acad-Indust Coop Soc* 2010;11(Suppl 11):4473–82 [In Korean, English abstract].
82. Kim JU, Shin SH. The development of pulse diagnostic algorithm. *J Inst Electron Eng Korea* 2010;37(Suppl 7):32–41 [In Korean, English abstract].
83. Ha IY, Youn YC, Youn DH, Choi CH, Lee YS, Lim SI, et al. Comparative study of speed, size and depth of pulse on the traditional pulse diagnosis and pulse analyzer. *Korean J Meridian Acupoint* 2011;28(Suppl 1):23–37 [In Korean, English abstract].
84. Jun YS, Chae WS, Cho MR, So CH, Choi CH, Jang KS. Study of the relationship between manual pulse diagnosis and machinery measurement on Qigu Inyoung comparison pulse diagnosis. *Korean J Orient Physiol Pathol* 2002;16(Suppl 1):201–8 [In Korean, English abstract].
85. Park YB, Hur W. Research for quantification of slow, wan-maek and rapid pulse by pulse/respiration rate on hyperthyroidism and hypothyroidism patients. *J Korea Inst Orient Med Diagn* 1999;3(Suppl 1):20–7 [In Korean, English abstract].
86. Lee HJ, Park YJ, Park YB, Oh HS. A study of correlation between pulse-respiration ratio and characteristics of thermal temperature. *J Korea Inst Orient Med Diagn* 2008;12(Suppl 1):103–30 [In Korean, English abstract].
87. Lee SW, Lee YJ, Lee HS, Kang HJ, Kim JY. Clinical study on the floating and sinking pulse detection with piezoresistive sensors and contact pressure control robot. *Korean J Orient Physiol Pathol* 2005;19(Suppl 6):1673–5 [In Korean, English abstract].
88. Lee Y, Lee J, Choi E, Lee H, Kim Y. Analysing of pulse wave parameter and typical pulse pattern for diagnosis in floating and sinking pulses. *Korean J Orient Med* 2006;12(Suppl 2):93–101 [In Korean, English abstract].
89. Lee J, Lee YJ, Lee HJ, Choi EJ, Kim JY. Proposal of pulse parameter useful for pulse wave analysis in Oriental medicine: preliminary study on floating and sinking pulses. In: *Proceedings of the Korean Institute of Electrical Engineers CICS*. 2006:244–6 [In Korean, English abstract].
90. Lee J, Lee Y, Ryu H, Kim J. Review on floating pulse and sinking pulse in the view point of tonometric measurement. *Korean J Orient Med* 2008;14(Suppl 2):113–9 [In Korean, English abstract].
91. Kim JY, Shin SH. Study on the selection of representative pulse wave. *J Korean Orient Med* 2008;29(Suppl 5):104–10.
92. Kim SH, Kim JU, Lee YJ, Kim KH, Kim JY. New algorithm of determining the floating and sinking pulse with a pulse diagnosis instrument. *Korean J Orient Physiol Pathol* 2009;23(Suppl 6):1221–5 [In Korean, English abstract].
93. Kown S, Kang HJ, Yim YK, Lee Y. A study on floating and sinking pulse by classification of pulse pattern through analysis of P-H volume curve at 5 applied pressure levels. *Korean J Meridian Acupoint* 2010;27(Suppl 1):13–22 [In Korean, English abstract].
94. Ryu HH, Lee J, Jeon YJ, Lee YJ, Lee SW, Kim JY. Modern medical scientific study on the string pulse. *Korean J Orient Physiol Pathol* 2008;22(Suppl 3):535–9 [In Korean, English abstract].
95. Kim SH, Kim JU, Jeon YJ, Kim KH, Kim JY. Method for determining the deficient and solid pulse with a new pulse wave parameter. *Korean J Orient Physiol Pathol* 2010;24(Suppl 1):42–7 [In Korean, English abstract].
96. Kim JU, Jeon YJ, Kim Y-M, Lee HJ, Kim JY. Novel diagnostic model for the deficient and excess pulse qualities. *Evid-Based Compl Alt* 2012. Article no. 563958.
97. Lee JC, Kang NS, Lee HJ, Kim JY, Kim JU. Relations between 10 primary pulse conditions based on doctors' pulse diagnoses. *Korean J Orient Physiol Pathol* 2010;24(Suppl 6):1077–81 [In Korean, English abstract].
98. Lee YJ, Lee J, Lee HJ, Ryu HH, Choi EJ, Kim JY. Characteristic Study of the pulse position on chon, kwan and chuck using the ultrasonic waves. *Korean J Orient Med* 2007;13(Suppl 3):111–7 [In Korean, English abstract].
99. Park SH, Hong SH. A study on the auto-diagnosis plethysmograph by novel algorithm for radial pulse detection. *J Biomed Eng Res* 1996;17(Suppl 2):241–6 [In Korean, English abstract].
100. Kil SK, Kim NH, Lee SM, Park SH, Hong SH. The study on the feature point recognition and classification of radial pulse. In: *Proceedings of the IEEK Summer Conference 22(Suppl 1)*. 1999:555–8 [In Korean, English abstract].
101. Lee JY, Lee JW, Lee MH. A study on the significant point detection algorithm and design of hardware for pulse automatic diagnosis. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference*. 1998:2255–8 [In Korean, English abstract].
102. Lee JY, Kim JH, Seo HW, Lee JW, Lee BC, Lee MH. A study of digital EPG diagnosis parameter for EPG standardization. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference*. 2000:3243–4 [In Korean, English abstract].
103. Han SC, Lee YD, Cho BS, Park YB, Hur W. A study on feature point detection algorithm in radial pulse. In: *Proceedings of the IEEK Summer Conference*. 2000:207–9 [In Korean, English abstract].
104. Kang MK. A special character parameter detection of Mac wave for a long-distance transmission. *J Korea Inst Maritime Inf Commun Sci* 2002;6(Suppl 4):610–5 [In Korean, English abstract].
105. Jeon Y, Lee J, Kim J, Lee L, Im J. Improvement of a characteristic point detection algorithm of arterial pulse. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference*. 2007:1916–7 [In Korean, English abstract].
106. Lee J. The study on the intellectual analysis algorithm for Oriental pulse parameters. *J Med Sys* 2007;31(Suppl 5): 345–9.
107. Im J. Estimation of the central aortic pulse using transfer function and improvement of an augmentation point

detection algorithm. *J Inst Electron Eng Korea SC* 2008;45(Suppl 3):68–79 [In Korean, English abstract].
108. Lee JY. The study on the web-based analysis system of Oriental pulse waveform. *Trans KIEE* 2012;61P(Suppl 1):9–12 [In Korean, English abstract].
109. Lee J. The systematical analysis of Oriental pulse waveform: a practical approach. *J Med Sys* 2008;32(Suppl 1):9–15.
110. Kil SK, Han SH, Kwon OS, Park SH, Hong SH. The classification and frequency analysis in radial pulse. In: *Proceedings of the KOSOMBE Autumn Conference*. 1998:263–4 [In Korean, English abstract].
111. Yoon YJ, Lee MH, Shin HS, Johng HM, Cho JH, Soh KS. Analysis of Fourier amplitude of pulse wave with varying contact pressure. *Korean J Orient Prev Med Soc* 1999;3(Suppl 1):173–9 [In Korean, English abstract].
112. Kil SK, Kim NH, Park SH, Min HK, Hong SH. A study on the recognition of human pulse using wavelet transform. In: *Proceedings from the Institute of Signal Processing and Systems Summer Conference 1(Suppl 1)*. 2000:269–72 [In Korean, English abstract].
113. Kil SK, Shen DF, Lee EH, Min HK, Hong SH. Recognition of feature points in ECG and human pulse using wavelet transform. *Trans KIEE SC* 2006;55(Suppl 2):75–81 [In Korean, English abstract].
114. Cho HS, Lee SS. Extraction of respiratory rate by using FFT for radial artery pulse waves acquired by clip-type pulsimeter with a Hall sensor. *J Korean Magnetics Soc* 2012;22(Suppl 5):178–82 [In Korean].
115. Kim GC, Lee JW, Ryu KH, Park DI, Shin WJ, Kang HJ. Study on the waveform analysis of radial artery pulse diagnosis using pulse meter and analyzer – the waveform analysis of left kwan pulse dignosis. *Korean J Orient Physiol Pathol* 2009;23(Suppl 1):186–91 [In Korean, English abstract].
116. Kim BH, Han GS, Lee WC, Sagong SJ, Ahn HS, Kim DH. A study on Maekjin system and Yangdorak diagnosis system by using neuro-fuzzy method in Korean Traditional Medicine. *J Inst Electron Eng Korea TE* 2000;37(Suppl 2):41–53 [In Korean, English abstract].
117. Choi YS, Kim KY, Hwang SY, Kim YJ, Lee SW, Kim HH, et al. Characteristic of the pulse wave in hypertension using pulse analyzer with array piezoresistive sensor. *Korean J Meridian Acupoint* 2007;24(Suppl 3):105–16 [In Korean, English abstract].
118. Ran W, Jae JI, Sung HP, Nam SJ. Estimation of central blood pressure using radial pulse waveform. In: *Proceedings 2007 International Symposium on Information Technology Convergence, ISITC*. 2007:250–3.
119. Ahn MC, Choi JK, Son IH, Lee SS, Kim KH. Estimated blood pressure algorithm of wrist wearable pulsimeter using by Hall device. *J Korean Magn Soc* 2010;20(Suppl 3):106–13 [In Korean].
120. Shin SH, Rhim HW, Park YJ, Park YB. A study of the cardiovascular aging effect on the pulse shape. *J Korea Inst Orient Med Diagn* 2005;9(Suppl 1):59–68 [In Korean, English abstract].
121. Lee NR, Lee SW, Kim SB, Lee YH. Analysis of pulse wave parameters according to aging for arteriosclerosis evaluation. *Korean J Meridian Acupoint* 2011;28(Suppl 4):79–89 [In Korean, English abstract].
122. Shin SH. Development of pulse wave analysis model with skin effect. *J Korea Inst Orient Med Diagn* 2011;15(Suppl 2):159–68 [In Korean, English abstract].
123. Lee JY, Shin SH. Development of the cardiovascular simulator for pulse diagnosis study. *J Korea Inst Orient Med Diagn* 2012;16(Suppl 1):19–26 [In Korean, English abstract].
124. Jang DS, Shin MS, Paek YS. Scientific palpation theory for the manufacture of the palpation diagnosis tool and health life. In: *Proceedings of the Korean Society for Emotion and Sensibility Summer Conference*. 2000:118–26 [In Korean].
125. Ryu HH, Lee SW, Lee J, Lee YJ, Kim JY. Study on sex difference in the pulse wave of healthy adults. *Korean J Orient Physiol Pathol* 2007;21(Suppl 5):1337–40 [In Korean, English abstract].
126. Kim GC, Kang HJ. Experimentational study on the pulsation of the elder women. *Korean J Orient Physiol Pathol* 2006;20(Suppl 1):83–7 [In Korean, English abstract].
127. Kim GC, Lee JW, Ryu KH, Kang HJ. Study on the character of the old aged pulsation. *J Korea Inst Orient Med Diagn* 2008;12(Suppl 2):1–7 [In Korean, English abstract].
128. Kim GC, Kim H, Shin SS, Lee HW. Study on the aged-pulse condition and the symptoms index of a disease. *Korean J Orient Prev Med Soc* 2008;12(Suppl 1):149–56 [In Korean, English abstract].
129. Kim JU, Kim SH, Jeon YJ, Ryu HH, Lee YJ, Lee HJ, et al. Clinical study of the floating-sinking pulse quantification analysis on ages, left/right, and palpation positions. *Korean J Orient Physiol Pathol* 2009;23(Suppl 5):1193–8 [In Korean, English abstract].
130. Kwon SM, Kang HJ, Yim YK, Lee YH. Analysis of arterial stiffness by age using pulse waveform measurement of 5-levels graded pressure. *Korean J Meridian Acupoint* 2010;27(Suppl 2):107–20 [In Korean, English abstract].
131. Ha Y, Cho M, Yun J, Jun K, Park S, Shin S. Characteristics of Pulse waves in various age categories and applicability of pulse wave to metabolic syndrome using pen-type piezoresistive sensor. *Korean J Orient Int Med* 2012;33(Suppl 3):257–71 [In Korean, English abstract].
132. Lee NR, Lee SW, Kim SB, Lee YH. Analysis of pulse wave parameters according to aging for arteriosclerosis evaluation. *J Acupunct Meridian Stud* 2012;5(Suppl 3):138–9.
133. Lee Y, Lee H, Lee J, Kang J, Lee S, Kim JY. The effect of BMI on the automatic pulse diagnosis in Korean traditional medicine. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference*. 2007:1904–5 [In Korean].
134. Lee YJ, Lee J, Lee HJ, Kim JY. A study on correlation the characteristics of blood vessel, BMI and Oriental medical pulse. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference*. 2008:407–8 [In Korean].
135. Lee Y, Lee J, Lee H, Kim J. The study for correlation characteristics on radial artery and floating/sinking pulse with BMI. *Korean J Orient Med* 2008;14(Suppl 3):121–6 [In Korean, English abstract].
136. Choi CH. Analysis of inyoung-chongu pulse measured on normal people. *Korean J Orient Physiol Pathol* 2010;24(Suppl 1):158–64 [In Korean, English abstract].
137. Lee YJ, Lee J, Lee HJ, Choi EJ, Kim JY. Effect of taking meal on pulse diagnosis in healthy subjects. *Korean J Orient Physiol Pathol* 2007;21(Suppl 6):1670–5 [In Korean, English abstract].
138. Yim YK, Kang HJ, Lee BR, Yang GY, Lee H, Kim KC. The effect of food intakes on radial pulse amplitude. *Korean J Meridian Acupoint* 2011;28(Suppl 2):13–22 [In Korean, English abstract].
139. Kim G, Lee J, Ryu G, Kim Y. Waveform changes of the radial pulsation followed by the food intakes in healthy subjects. *Korean J Orient Med* 2011;17(Suppl 3):87–96 [In Korean, English abstract].
140. Yim YK, Park KS. A study on the effect of food intake on radial pulse using Fourier analysis. *J Korean Orient Med* 2011;32(Suppl 4):139–48 [In Korean, English abstract].
141. Kim D, Kim JR, Kim DR. A bibliographical research of the correlation among sasang constitutional disease and the pulse diagnosis. *J Pharmacopunct* 2003;6(Suppl 3):23–37 [In Korean, English abstract].
142. Lee SW, Joo JC, Kim KY, Kim JY. Clinical study on the Sasang constitutional pulse using array piezoresistive sensor. *J*

Sasang Constitutional Med 2006;18(Suppl 1):118–31 [In Korean, English abstract].
143. Lee S, Kim H, Ryu H. A study on the Sasang constitutional differences in the pulse wave of Korean healthy adult men. *Korean J Orient Med* 2007;13(Suppl 2):71–4 [In Korean, English abstract].
144. Choi YS, Kim KY, Hwang SY, Choi CW, Kim HH, Joo JC. A comparative study on the pulse wave variables and Sasang constitution in hypertension patients and healthy Subjects. *J Sasang Constitutional Med* 2007;19(Suppl 2):127–42 [In Korean, English abstract].
145. Lee JH, Kim YJ, Hwang MW, Kim JY, Lee EJ, Song IB, et al. Survey study about Sasangin's characteristics of face, voice, skin and pulse diagnosis. *J Sasang Constitutional Med* 2007;19(Suppl 3):126–43 [In Korean, English abstract].
146. Song MS, Park HS, Kim OY, Kim BS, Yang DH, Choi CH. Relationship of inyoung-chongu pulse, BMI and Sasang constitution using pulse diagnosis device. *Korean J Orient Physiol Pathol* 2011;25(Suppl 2):339–44 [In Korean, English abstract].
147. Shin SH, Kim JY. Study on the discrimination of constitution using pulse wave. *Korean J Orient Physiol Pathol* 2008;22(Suppl 6):1403–9 [In Korean, English abstract].
148. Kim J, Kim S, Lee Y, Jeon Y, Kim K, Kim J. Improvement and limitations in the Sasang constitution diagnosis by the instrument-based pulse diagnosis. *Korean J Orient Med* 2009;15(Suppl 2):93–100 [In Korean, English abstract].
149. Shin SH, Kim JY. Comparisons of the accuracy of classification methods in Sasang constitution diagnosis with pulse waves. *J Korea Contents Association* 2009;9(Suppl 10):249–57 [In Korean, English abstract].
150. Nam TH, Park YJ, Park YB. Gender-related differences in the second derivative of photoplethysmogram waveforms in the fourth decade. *J Korean Orient Med* 2002;23(Suppl 3):1–10 [In Korean, English abstract].
151. Lee JH, Kim JY, Kim SJ, Seo JH, Sung WY. Effects of acupuncture at GV 20(Baihui) evaluated by the second derivative of photoplethysmogram waveform under stress. *J Orient Neuropsychiatry* 2010;21(Suppl 3):19–27 [In Korean, English abstract].
152. Park YB, Park YJ, Ko YI. Relationships of pulse waveform parameters to mood states and chronic fatigue. *J Altern Complem Med* 2012;18(Suppl 11):1050–60.
153. Nam TH, Koh HK, Park YB. Elevated levels of serum lipids accelerate biological vascular aging evaluated by the second derivative of photoplethysmogram waveform in middle-aged adults. *J Korean Acupunct Moxibustion Soc* 2002;19(Suppl 3):126–37 [In Korean, English abstract].
154. Nam KC, Ryu CY, Jung WH, Kim JT, Park JH, Kim DW. Diagnosis of neuropathic foot of diabetics using photo-plethysmography. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference. ICS*. 2005:39–41 [In Korean, English abstract].
155. Nam TH, Park YB, Park YJ, Shin SH. Age-related changes of the finger photoplethysmogram in frequency domain analysis. *J Korea Inst Orient Med Diagn* 2008;12(Suppl 1):42–62 [In Korean, English abstract].
156. Yeo K, Yoon I, Kim J, Bang S, Moon S. *J Korean Acupunct Moxibustion Soc* 2010;27(Suppl 2):23–30 [In Korean, English abstract].
157. Park SI, Whang MC, Kim JW, Mun SC, Ahn SM. Autonomic nervous system response affected by 3D visual fatigue evoked during watching 3D TV. *Korean J Sci Emotion Sensibility* 2011;14(Suppl 4):653–62 [In Korean, English abstract].
158. Lee C, Shin HS, Kong I, Lee M. Analysis of arterial stiffness variation by photoplethysmographic DC component. *J Biomed Eng Res* 2011;32(Suppl 2):109–17 [In Korean, English abstract].
159. Lee CK, Yoo SK. An analysis of the relationship between self-reported anxiety, depressiveness and parameters of heart rate variability based on photoplethysmography. *Korean J Sci Emotion Sensibility* 2012;15(Suppl 3):345–54 [In Korean, English abstract].
160. Kong JO, Koh SB, Jang SJ, Cha BS, Jung HK, Choi HY, et al. Relationship between job stress and pulse wave velocity as a cardiovascular risk factor. *Korean J Occup Environ Med* 2004;16(Suppl 4):450–8 [In Korean, English abstract].
161. Park M, Cho J, Jang J, Lee K. Clinical Study of correlation between retention of fluid and PWV/ABI. *Korean J Orient Med* 2004;10(Suppl 2):73–8 [In Korean, English abstract].
162. Park Y, Hong J, Shin W, Jeong D, Rhee J, Kim S, et al. Effects of chungpyesagan-tang on arterial stiffness and pulse pressure in acute stroke patients. *Korean J Orient Int Med* 2006;27(Suppl 2):416–28 [In Korean, English abstract].
163. Kim EG, Hwang DS, Cho JH, Jang JB, Lee JM, Lee CH, et al. A study about correlation between hot flush and pulse wave velocity (PWV)/ankle-brachial index (ABI) in climacteric women. *J Orient Obstet Gynecol* 2010;23(Suppl 1):53–64 [In Korean, English abstract].
164. Kim GC, Park SW, Kim YS. Effect of heart rate variability, pulse wave velocity in women of breast cancer patients care by mountain cultivated ginseng pharmacopuncture. *J Korea Inst Orient Med Diagn* 2011;15(Suppl 3):245–60 [In Korean, English abstract].
165. Ko K, Kim K, Kim J, Lee S, Joo J. Comparative study on the pulse wave variables and Sasang constitution in cerebral infarction patients and healthy subjects. *J Pharmacopunct* 2007;10(Suppl 2):119–32 [In Korean, English abstract].
166. Kim EG, Heo H, Nam KC, Hur Y. Pulse wave parameters changes between normotensive and hypertensive group. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference*. 2008:1999–2000 [In Korean, English abstract].
167. Kang HJ, Kwon YS, Kim DL, Kim KC, Yim YK. A study on wiry pulse in hypertensive patients analyzed at 5 levels of applied pressure using 3 dimensional pulse imaging analyzer. *Korean J Meridian Acupoint* 2010;27(Suppl 1):1–12 [In Korean, English abstract].
168. Hwang J, Jung S, Jung S. The diagnostic values of Ryodoraku and pulse analysis for respiratory disease patients. *Korean J Orient Int Med* 2007;28(Suppl 3):560–9 [In Korean, English abstract].
169. Shen F, Lee S, Jung H, Jung S. The diagnostic values of Ryodoraku and pulse analysis for a portion of respiratory disease. *Korean J Orient Int Med* 2008;29(Suppl 3):535–42 [In Korean, English abstract].
170. Kim GC, Kim YS. A study on the pulse wave factor according to BMI and period of sterility on female. *Korean J Orient Med* 2012;18(Suppl 2):139–49 [In Korean, English abstract].
171. Seo CW, Kim GC, Kim YS. A study on the pulse wave parameter in non delivery and delivery women. *Korean J Meridian Acupoint* 2012;29(Suppl 2):200–15 [In Korean, English abstract].
172. Park SJ, Kim KY, Lee SW, Kwon YM, Kil EY, Joo JC. Comparative study on the pulse wave variables and sasang constitution in diabetes mellitus patients and healthy subjects. *Korean J Orient Physiol Pathol* 2007;21(Suppl 6):1601–10 [In Korean, English abstract].
173. Kim HK, Yoon SH, Ryu JM, Jang SY, Lee JS, Eom GH, et al. Association of skin sympathetic tone or cardiovascular reactivity on the fatigue index in patients with functional dyspepsia. *Korean J Orient Int Med* 2005;26(Suppl 2):390–7 [In Korean, English abstract].

174. Shin KY, Lee TB, Jin SO, Choi SH, Yoo SK, Huh Y, et al. Characteristics of the pulse wave in patients with chronic gastritis and the healthy in Korean medicine. In: *Proceedings of the Annual International Conference of the IEEE. EMBS*. 2012:992–5.
175. Shin YJ, Kim YB, Yoon SH. A clinical study of atopic dermatitis patients as measured by pulse diagnostic apparatus. *J Korean Orient Med Ophthalmol Otolaryngol Dermatol* 2008;21(Suppl 2):112–9 [In Korean, English abstract].
176. Won JK, Jung SK, Kim DE, Lim JY, Kwon YD, Yeom SR, et al. Study on the Radial pulse wave variables and heart rate variability after acupuncture stimulation. *Korean J Orient Physiol Pathol* 2009;23(Suppl 1):237–44 [In Korean, English abstract].
177. Yim YK, Lee H, Lee BR, Lee YH, Yoon YJ, Ro JY. Effect of Sa-Am acupuncture on radial pulse; a comparative study of stomach-tonification and spleen-tonification. *Korean J Meridian Acupoint* 2011;28(Suppl 3):25–32 [In Korean, English abstract].
178. Kim S, Lee H. The effect of Sa-Am lung sedating acupuncture on wrist pulse in healthy human subjects. *J Korean Acupunct Moxibustion Med Soc* 2012;29(Suppl 2):43–57 [In Korean, English abstract].
179. Lee S, Kim K, Oh S, Kwon Y, Joo J. Effects of bee venom acupuncture on heart rate variability, pulse wave, and cerebral blood flow for types of Sasang Constitution. *J Pharmacopunct* 2009;12(Suppl 1):35–42 [In Korean, English abstract].
180. Park SW, Kim YS, Hwang WD, Kim GC. Effect of pulse-wave factors in middle aged women by mountain cultivated ginseng pharmacopuncture original articles. *J Pharmacopuncture* 2011;14(Suppl 1):35–49 [In Korean, English abstract].
181. Kang SY, Jang IS, Kim LH. Comparative studies on the concordance rate of pulse condition interpretation between interpreters and pulse analyser. *Korean J Meridian Acupoint* 2011;28(Suppl 4):91–9 [In Korean, English abstract].
182. Ryu H, Jeon YJ, Kim JY, Lee JH, Woo YJ, Lee YJ, et al. Effect of hematocrit level on the radial pulse wave. *Korean J Orient Physiol Pathol* 2009;23(Suppl 5):1035–40 [In Korean, English abstract].
183. Lee YJ, Woo YJ, Lee HJ, Jeon YJ, Kim JY. A study for Oriental medicine pulse diagnosis of pulse wave analysis on left/right blood vessel. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference*. 2009:1968–9 [In Korean].
184. Ryu KH, Kim GC, Kang HJ. The difference of pulse waveform on the radial artery by applied pressure and position. In: *Proceedings of the 49th International Symposium of Korean Society of Life Science*. 2008:35.
185. Kim JY, Jeon YJ, Kim JU, Lee HJ, Lee J, Ryu HH, et al. A clinical study of the pulse wave characteristics at the three pulse diagnosis positions of chon, gwan and cheok. *Evid-Based Compl Alt* 2011. Article no. 904056.
186. Kwon KH, Lee HB. Design and implementation of pulse monitoring system for U-healthcare. *J Digital Contents Society* 2008;9(Suppl 4):601–6 [In Korean, English abstract].
187. Kim GH. Ubiquitous health care smart system base on Bluetooth. *J Korea Inst Inf Commun Eng* 2012;16(Suppl 6):1153–7 [In Korean, English abstract].
188. Hwang D, Lee YW. Development of wrist type ubiquitous optical sensor. In: *Proceedings of the Korean Institute of Maritime Information and Communication Sciences Spring Conference B*. 2008:129–32 [In Korean].
189. Ye SY, Noh YH, Jeong DU. Implementation of the wearable PTT measurement system for health monitoring during daily life. *J Korea Institute of Maritime Information and Communication Sciences* 2011;15(Suppl 1):220–6 [In Korean, English abstract].
190. Lim MJ, Jung HW, Lee KY. In the ubiquitous environment with wireless heart rate meter ECG status information system. *J Inst Webcasting, Internet Telecommun* 2011;11(Suppl 2):51–6 [In Korean, English abstract].
191. Jung SJ, Seo YS, Chung WY. Pulse wave analysis system using wrist type oximeter for u-Health service. *J Korean Sensors Society* 2010;19(Suppl 1):17–24 [In Korean, English abstract].
192. Seo HW, Lee JY, Kim JH, Hwang SC, Lee MH, Lee JW. A Study on WWW-based digital pulse database system. In: *Proceedings of the Korean Institute of Electrical Engineers Summer Conference D*. 2000, 3241–2 [In Korean, English abstract].
193. Lee JY, Seo HW, Kim JH, Lee JW, Lee MH. A study on EPG Internet data base system for pulse diagnosis objectification. In: *Proceedings of the Korean Institute of Electrical Engineers Autumn Conference. D*. 2000:851–3 [In Korean, English abstract].
194. Lee J, Kim J, Lee J, Hwang S, Lee B, Jeong K, et al. The study on the web-based clinical database management system of Oriental pulse waveform. *J Med Sys* 2001;25(Suppl 5):277–84.
195. Yang DI, Park SH, Chon KH. Design and implementation of pulse-diagnosis ontology in ubiquitous computing environment. *J Korean Soc Med Inf* 2008;14(Suppl 1):45–54 [In Korean, English abstract].
196. Lee YB, Lee BW, Lee MH. Implementation of wearable sensor glove using pulse-wave sensor, conducting fabric and embedded system. *J Control Automation Sys Eng* 2007;13(Suppl 3):205–9 [In Korean, English abstract].
197. Jeon YJ, Lee J, Lee YJ, Woo YJ, Ryu HH, Kim JY. Design of multi-array pulse diagnosis sensor with FDB process. In: *Proceedings of the Korean Institute of Electrical Engineers Conference. CICS*. 2008:367–8 [In Korean].